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Internet Use and Child Development: Validation of the Ecological Techno-Subsystem

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ABSTRACT

Johnson and Puplampu recently proposed the *ecological techno-subsystem*, a refinement to Bronfenbrenner's theoretical organization of environmental influences on child development. The ecological techno-subsystem includes child interaction with both living (e.g., peers) and nonliving (e.g., hardware) elements of communication, information, and recreation technologies in immediate or direct environments. The theoretical techno-subsystem requires empirical validation. Parents of 128 children in first through sixth grade consented to cognitive developmental assessment of their children and completed questionnaires on children's use of the Internet at home and family socioeconomic characteristics. In general, indices of home Internet use accounted for more of the variance in children's cognitive development than did indices of socioeconomic status. The ecological techno-subsystem furthers our understanding of environmental influences on child development by emphasizing the impact of digital technologies on cognitive growth during childhood.

Keywords

Ecological techno-subsystem, Child development, Child cognition, Ecological theory

Introduction

According to the Corporation for Public Broadcasting (2002), the prevalence of Internet use among American 6 to 8 year old children doubled between 2000 and 2002 (from 27% to 60%, across all locations, at least one a week). Approximately 20% of Canadian 9 year old children access the Internet through their own personal computer (Media Awareness Network, 2006). The Office of Communication (2007) reported that 7% of British 10-year-olds have a webcam. In Australia, nine in ten families have home Internet connectivity and 75% have broadband access (Australian Communications and Media Authority, 2007). Trends indicate continued increase in the number of children accessing the Internet, the amount of time they spend online, and the complexity of their online behavior (Livingstone & Helpsper, 2007).

Historically, panic surrounds the introduction of new technologies, particularly in relation to children and youth (Johnson, 2006). For example, in the 19th century, "the telegraph enabled a young woman, against her father's wishes, to maintain a flirtation with a number of men on the wire" (Quigley & Blashki, 2003, p. 311). In the 21st century, there are two conflicting public anxieties surrounding children and the Internet; first, that the Internet may harm children, for example, by exposure to inappropriate content (Media Awareness Network, 2008) and, second, that children without Internet access are cognitively and socially disadvantaged (Jackson et al., 2006). Public anxiety surrounding the digital divide (Burnett & Wilkinson, 2005; Livingstone & Helpsper, 2007), increasingly complex school Internet literacy curriculum (Johnson, 2007a; Takahira, Ando, & Sakamoto, 2007), and social policy initiatives directed at enhancing childhood Internet access (Sandvig, 2003) reveal the extent to which Internet use is perceived as developmentally appropriate (if not required). Indeed, there is mounting evidence that using the Internet provides children with cognitive and social benefits (Greenfield & Yan, 2006).

Internet Use and Child Development

Particularly during periods of rapid development associated with childhood, Internet use stimulates cognitive and psychosocial development (Johnson, 2006; Young, 2007). Fish and colleagues (2008) investigated home computer experience and cognitive development among preschool children in inner-city Head Start programs. Data was collected from parents regarding the children's experience with computers in the home environment, including access to a computer, time spent on a computer, and types of computer programs used. Two hundred participating children were administered standardized tests of cognitive development. After controlling for parent's education and household income, children who had home computer access had significantly higher scores of cognitive development than did children who did not have home access. Frequency of children's computer use also related to cognitive development. The investigators concluded that early computer use at home was a positive influence on young children's cognitive development.

The Internet, although rich in graphic display, is primarily a text-based medium; “the more a child uses the Internet, the more he/she reads” (Jackson et al., 2007, p. 188). Li and Atkins (2004) concluded that computer exposure during the preschool years was associated with subsequent school readiness. Jackson and colleagues (2006) provided low income children with home-based Internet access and continuously recorded time online. “Findings indicated that children who used the Internet more had higher scores on standardized tests of reading achievement and higher grade point averages 6 months, 1 year, and 16 months later than did children who used the Internet less” (p. 429). Fuchs and Wößmann (2005) inferred, having controlled for socioeconomic status, “a negative relationship between home computer availability and academic achievement, but a positive relationship between home computer use for Internet communication” (p. 581). From a developmental perspective, Internet use stimulates cognitive processes involved in interpreting text and images (Johnson, 2006). Metacognitive processes such as planning, search strategies, and evaluation of information are exercised when navigating websites (Tarpley, 2001).

DeBell and Chapman (2006) concluded that Internet use promotes cognitive development in children, “specifically in the area of visual intelligence, where certain computer activities -- particularly games -- may enhance the ability to monitor several visual stimuli at once, to read diagrams, recognize icons, and visualize spatial relationships” (p. 3). Van Deventer and White (2002) observed proficient 10- and 11-year-old video gamers and noted extremely high levels of self-monitoring, pattern recognition, and visual memory. In a comprehensive review of the literature of the time (when interactive digital games were relatively unsophisticated), Subrahmanyam, Kraut, Greenfield, and Gross (2000) concluded that “children who play computer games can improve their visual intelligence” (p. 128). It should be noted, however, that playing video games has also been linked to childhood distractibility, over-arousal, hostility, and aggression (Anderson, Gentile, & Buckley, 2007; Funk, Chan, Brouwer, & Curtiss, 2006).

While Internet use during childhood has been associated with negative developmental outcomes, research increasingly suggests that the Internet provides children with more developmental advantages than disadvantages (Greenfield & Yan, 2006). Comprehensive theoretical description of the developmental impact of Internet use is required. The recently proposed *ecological techno-subsystem* (Johnson & Puplampu, 2008) provides a conceptual framework for understanding the effect of Internet use on child development.

Ecological Systems Theory and the Techno-Subsystem

Contemporary theories of child development assume that biological predispositions and environmental experiences, to varying combined degrees, result in social, emotional, and cognitive growth. Cognitive-developmental theories assume that neurological maturation and environmental experience result in individuals who are progressively more able to function effectively in their environments (Luria, 1976). A socio-cultural orientation to child cognitive development presupposes that “through participation in activities that require cognitive and communicative functions, children are drawn into the use of these functions in ways that nurture and scaffold them" (Vygotsky, 1986, pp. 6-7). Ecological systems theory (Bronfenbrenner, 1979) presents a particularly comprehensive view of environmental influences on development by situating the child within a system of relationships affected by multiple levels of the surrounding environment.

Bronfenbrenner (1979) organized the contexts of development into five nested environmental systems, with bi-directional influences within and among systems. The *microsystem* refers to the immediate environment and includes, most notably, home and school interactions. The *mesosystem* is comprised of connections between immediate environments (e.g., home-school interactions). The *exosystem* includes environmental settings that indirectly affect child development (e.g., the parent's workplace). The *macrosystem* refers to overarching social ideologies and cultural values. The *chronosystem* highlights the effect of time on all systems and all developmental processes. As his theory evolved, Bronfenbrenner (2005) proposed a bioecological perspective which views the child's own biology as part of the microsystem. Bronfenbrenner (1989) described human development as “the progressive, mutual accommodation, throughout the life course, between an active, growing human being, and the changing properties of the immediate settings in which the developing person lives, as this process is affected by the relations between these settings, and by the larger contexts in which the settings are embedded” (p. 188).

Ecological systems theory (Bronfenbrenner, 1979) emerged prior to the Internet revolution and the developmental impact of then available technology (e.g., television) was conceptually situated in the child's microsystem. Johnson and Puplampu (2008) recently proposed the *ecological techno-subsystem*, a dimension of the microsystem. As illustrated in Figure 1, the techno-subsystem includes child interaction with both living (e.g., peers) and nonliving (e.g., hardware) element of communication, information, and recreation technologies in immediate or direct environments. Since tools, by definition, extend human capabilities, interaction with increasingly complex tools requires increasingly complex cognitive processes (Johnson, 2008; Nickerson, 2005). The Internet extends human access to information and communication and provides cognitive scaffolding (e.g., search engines and e-directories) which allows for higher-order processes such as evaluation and application of information to solve real problems.

Research Issues and Questions: Validation of the Ecological Techno-Subsystem

The utility of the recently proposed ecological techno-subsystem in explaining child development has not been established nor investigated. From an ecological perspective, the techno-subsystem mediates bidirectional interaction between the child (i.e., bioecology) and the family (i.e., microsystem). Does the techno-subsystem contribute to increased understanding of the mechanisms of cognitive development during childhood? Which is the better predictor of cognitive development during childhood, -- indices of home Internet use (elements of the techno-subsystem) or family socioeconomic characteristics (elements of the microsystem)?

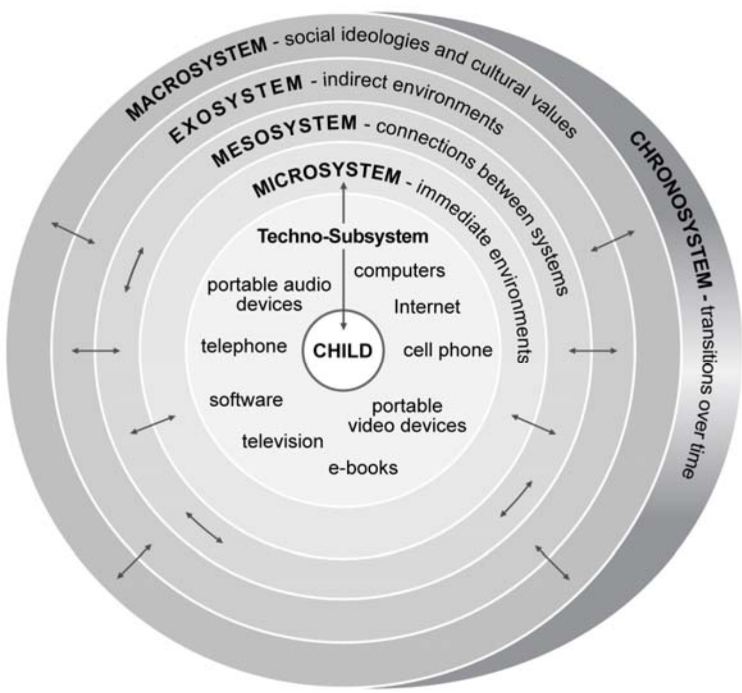

Figure 1. The Ecological Techno-Subsystem (Johnson & Puplumpu, 2008)

Methods

Participants

Parents of children in first through sixth grade (N = 151) attending an elementary school in suburban Western Canada were invited to participate in the study. Parents completed a questionnaire and consented to cognitive developmental assessment of their children. One hundred twenty-eight signed consent forms and completed parent questionnaires were returned to the school. Participating children (62 males and 66 females) ranged in age from 6 years, 4 months to 12 years, 5 months; 14.8% of the children were in first grade, 12.5% were in second grade, 15.6%

were in third grade, 25.0% were in fourth grade, 16.4% were in fifth grade, and 15.6% were in sixth grade. Twelve of the 128 children were funded for special needs (e.g., communication disorder, learning disability, behavior disorder, medical condition).

Measures

Three constructs, corresponding to three ecological systems/subsystems, were measured: child cognitive development (bioecology), indices of child use of the Internet at home (techno-subsystem), and family socioeconomic characteristics (microsystem).

Child Cognitive Development

Children's cognitive development was measured with one subtest from the fourth edition of Wechsler Intelligence Scale for Children (WISC-IV; Wechsler, 2003) and three subtests from the Cognitive Assessment System (CAS; Das & Naglieri, 2001). Subtests were selected to ensure comprehensive representation of child cognitive development (i.e., language, metacognition, perception, and memory). Expressive language was assessed with the WISC-IV vocabulary subtest (child provides verbal definitions to orally presented words). WISC-IV subtest scoring criteria was maintained; norms were not required because all comparisons occurred within the group of 128 children. With respect to the CAS, the matching numbers subtest measured metacognitive planning (find the two numbers that are the same in a series of numbers), the nonverbal matrices subtest assessed visual perception (select an option that best completes a visual matrix), and the word series subtest measured short-term auditory memory (repeat a string of words presented orally); CAS scoring criteria was maintained.

Each of the 128 children was individually administered the four cognitive subtests by one of two examiners (an educational psychologist and a trained research assistant). Rapport was initiated by in-class introduction of the examiners, explanation of testing procedures, and response to class questions. Rapport was further established by individual child-examiner interaction walking from the classroom to the testing room and, as required, upon entry into the testing room. Each individual assessment was complete in approximately 15 minutes. Table 1 presents a summary of cognitive developmental measures and description of children's cognitive scores.

Table 1. Summary of Cognitive Developmental Measures and Description of Children's Scores

			Children's Raw Scores		
Cognitive Skill	Test and Subtest	*N*	*Range*	*Mean*	*SD*
Expressive Language	WISC Vocabulary	127	14 – 54	30.7	8.38
Metacognitive Planning	CAS Matching Numbers	126	1 – 11	7.1	1.84
Visual Perception	CAS Nonverbal Matrices	128	4 – 33	14.3	4.64
Auditory Memory	CAS Word Series	128	2 – 16	9.7	2.51

Indices of Child Home Internet Use

The parent questionnaire included two yes/no response items: Do you have the Internet in your home? Does your child use the Internet at home? Approximately 83% of families (106/128) reported home Internet access; 71.9 % (92/128) indicated that their child used the Internet at home. For purposes of the current investigation, five indices of child home Internet use were obtained from parental response to questionnaire items. First, parents reported the number of years of home Internet access (range 0.2 to 12 years, mean 5.2 years, standard deviation 2.96 years). Additionally, parents who reported that their child used the Internet at home were asked to respond to the open-ended questionnaire item, what does your child do when he/she uses the Internet at home? Thematic analysis of 90 parental responses to the open-ended item revealed four categories or types of child home online behavior: learn (e.g., schoolwork, math practice, research for assignments), play (e.g., play games, have fun with friends), browse (e.g., visit websites, find things of interest), and communicate (e.g., email, chat). Approximately 17% of parents responded to the open-ended questionnaire item with description that suggested one type of child online behavior, 35.9% described two, 14.1% described three, and 3.1% described four types of online behavior. Using the Internet at home to learn was reported in 65 cases, to play was reported in 57 cases, to browse in 35 cases, and to communicate in 27 cases. Thus, the five indices of child home Internet use included: 1) the continuous variable years of home Internet access and the dichotomous (reported-unreported) variables of child home Internet use to 2) learn, 3) play, 4) browse, and 5) communicate.

Family Socioeconomic Characteristics

The parent questionnaire assessed five family characteristics commonly used to determine socioeconomic status (Bradley & Corwyn, 2002; Sirin, 2005). Two items queried father's and mother's employment status. Approximately 70% of mothers and 96% of fathers were employed, full-time or part-time. Two questionnaire items requested father's and mother's level of education, coded as: elementary = 1, junior high school = 2, high school incomplete = 3, high school complete = 4, technical school/college (complete or incomplete) = 5 and university (complete or incomplete) = 6. The mean educational level of mothers was 4.79 (SD = 0.95) suggesting that many mothers had post-secondary education; the mean educational level of fathers was 4.45 (SD = 1.02) suggesting that some fathers had post-secondary education. The final socioeconomic item on the questionnaire asked parents to indicate annual family income by selecting one of the following options: < $20 000 = 1, $20 000 to $40 000 = 2, $40 000 to $60 000 = 3, $60 000 to $80 000 = 4, $80 000 to $100 000 = 5, > $100 000 = 6. Annual income for participating families was approximately $60,000 CD (M = 4.07, SD = 1.48).

Table 2 presents a summary of measured constructs which includes: four tests of children's cognitive development, five indices of children's home Internet use, and five family socioeconomic characteristics. Which are the better predictors of cognitive development during childhood, -- elements of the microsystem or elements of the techno-subsystem? Two series of stepwise regression analysis were conducted with the four cognitive development scores as the dependant variables. In the first regression analyses, family socioeconomic characteristics (elements of the microsystem) were the independent variables. In the second analyses, indices of home Internet use (elements of the techno-subsystem) were the independent variables.

Table 2. Description of Constructs and Measures

Ecological System	System Elements	Specific Measures
Bioecology	Cognitive Development	Expressive Language
		Metacognitive Planning
		Visual Perception
		Auditory Memory
Techno-Subsystem	Home Internet Use	Years of Internet Access
		Online Learning
		Online Playing
		Online Browsing
		Online Communication
Microsystem	Family Characteristics	Father Employment
		Mother Employment
		Father Education
		Mother Education
		Annual Family Income

Results

Results of analyses revealed that family socioeconomic characteristics (elements of the microsystem) explained a modest (but significant) amount of the variation in children's cognitive development scores. As presented in Table 3, adjusted R^2 values indicated that father's level of education accounted for approximately 7% of the variation in children's level of expressive language (as measured by the WISC-IV vocabulary subtest), 5% of the variation in children's visual perception and auditory memory (as measured by the CAS nonverbal matrices subtest and CAS word series subtest, respectively). Whether or not mothers were employed, part-time or full-time, accounted for approximately 6% of the differences in children's capacity to execute metacognitive functions such as planning (as measured by the CAS matching numbers subtest). While the other measures of familial socioeconomic status (e.g., mother's education and family income) explained some of the variance in children's cognitive development, such measures did not improve upon the predictive utility of father's education or maternal employment; variation is prerequisite to prediction. Almost all fathers were employed and almost all mothers had finished high school. For participating middle-class families, father's education and mother's employment were more sensitive to children's cognitive development scores than were family income, father's employment, and mother's education.

Table 3. Stepwise Regression Analysis: Family Characteristics Predicting Child Cognitive Development

Cognitive Score	Predictor	Beta Weight	*t* value	$R^2_{(adj)}$	*F* value
Expressive Language	Father Education	.292	2.70**	.074	(1, 78) = 7.29**
Metacognitive Planning	Mother Employed	.270	2.46*	.061	(1, 77) = 6.05*
Visual Perception	Father Education	.244	2.22*	.047	(1, 78) = 4.93*
Auditory Memory	Father Education	.258	2.36*	.054	(1, 78) = 5.55*

*p < .05; **p < .01

Results of analyses further revealed that indices of home Internet use (elements of the techno-subsystem), in general, explained more of the variation in children's cognitive development than did family socioeconomic characteristics (elements of the microsystem). Summarized in Table 4, specific types on online behavior (i.e., learning, communicating, and playing) and years of home Internet access combined to predicted child cognitive developmental outcomes. Indicated by adjusted R^2, children's online communication, years of home Internet access, and online learning (as reported by parents) accounted for approximately 29% of the variation in children's level of expressive language as measured by the WISC-IV vocabulary subtest. Online learning and communicating (reported-unreported) combined to explain 13.5% of the variation in children's metacognitive planning. Online learning and playing (reported-unreported) combined to explain 10.9% of the variation in children's auditory memory. Years of home Internet access explained approximately 3% of the differences in children's visual perception scores. With the exception of visual perception, indices of home Internet use (elements of the techno-subsystem) were better predictors of children's cognitive development than were family socioeconomic characteristics (elements of the microsystem).

Table 4. Stepwise Regression Analysis: Home Internet Use Predicting Child Cognitive Development

Cognitive Score	Predictor/s	Beta Weight	*t* value	$R^2_{(adj)}$	*F* value
Expressive Language	Online Communication	.344	4.00***		
	Years of Internet Access	.263	3.12 **		
	Online Learning	.256	2.99**	.287	(3, 101) = 14.97***
Metacognitive Planning	Online Learning	.287	3.03**		
	Online Communication	.201	2.12*	.135	(2, 101) = 9.06***
Visual Perception	Years of Internet Access	.192	1.99*	.028	(1, 104) = 3.98*
Auditory Memory	Online Learning	.242	2.60*		
	Online Playing	.228	2.46*	.109	(3, 101) = 14.97***

*p < .05; **p < .01; ***p < .001

Discussion

A variety of mechanisms linking family socioeconomic status to child cognitive development have been proposed including parenting (Petrill, Pike, Price, & Plomin, 2004; Mistry, Biesanz, Chien, Howes, & Benner, 2008) and resources (Bradley & Corwyn, 2002). For the current sample of middle class children, paternal education and maternal employment were associated with measures of child cognitive development. More educated fathers tended to have offspring who scored high on three of the four cognitive measures (expressive language, visual perception, and auditory memory). Mothers who were employed tended to have children who scored high on the measure of metacognitive planning. Educated fathers and employed mothers may genetically transmit to their offspring some neurological processing advantage (bioecology). Simultaneously, educated fathers may provide enhanced language models and stimulating environments that facilitate the cognitive development of their children (microsystemic influence). Employed mothers may provide models of organization and place increased demands on children to self-regulate thereby enhancing the metacognitive planning abilities of their offspring (microsystemic influence).

Family socioeconomic status (as measured and for the current sample) accounted for 5% to 7% of differences in child cognitive development scores. In contrast, indices of home Internet use (as measured and for the current sample) accounted for 3% to 29% of differences in child cognitive development scores. Meta-analysis confirms that the impact of socioeconomic status on academic achievement is eroding over time (Sirin, 2005). Increasingly effective structures of social equalization (e.g., public education, quality daycare, preschool intervention, and prenatal programs) and the expanding middle class create the need for more precise description of home environments. Current results suggest that indices of home Internet use (i.e., elements of the ecological techno-subsystem) provide more useful information regarding cognitive development than do family socioeconomic characteristics (elements of the microsystem).

Only two of five family socioeconomic characteristics added to the regression equation, suggesting that some measures (i.e., family income, father employment, and mother education) did not differ in relation to children's cognitive development. In contrast, four of the five indices of home Internet use during childhood added to the regression equation, suggesting that these measures differed in relation to children's cognitive development. In the context of the current investigation, socioeconomic status is a crude construct relative to home Internet use. Internet use includes both organized (e.g., search) and disorganized (e.g., browse) interactions with both human (e.g., chat) and nonhuman (e.g., database) elements in online environments (Johnson & Kulpa, 2007). Internet use is a complex set of behaviors that vary widely across individuals and that is influenced by cognitive and personality characteristics (Joinson, 2003). For the current sample of children, patterns of home Internet use explained more of the variation in cognitive development than did family socioeconomic characteristics.

In the context of middle class families, elements in the techno-subsystem (e.g., Internet access) may not necessarily facilitate child cognitive development; effective use of those elements, highly dependent upon parent behavior, may promote development. For example, Cho and Cheon (2005) surveyed families and found that parents' perceived control, obtained through shared web activities and family cohesion, reduced children's exposure to negative Internet content. Lee and Chae (2007) reported a positive relationship between parental mediation techniques (website recommendation and Internet co-use) and children's educational attainment. In the current investigation, the cognitive experiences provided to children by employed mothers may include Internet skills instruction (e.g., sending email) and models of information management (e.g., accessing websites for information). Such experiences, over time, may provide children with enhanced opportunities to direct their own cognitive development via increasingly sophisticated uses of the Internet. According to Livingston and Bober (2005), "a new divide is opening up between those for whom the internet is an increasingly rich, diverse, engaging and stimulating resource and those for whom it remains a narrow, unengaging, if occasionally useful, resource of rather less significance" (p. 2).

Bruner (2005) recently reiterated that "our minds appropriate ways of representing the world from using and relating to the codes or rules of available technology" (p. x). Cognitive abilities prerequisite to utilization of Internet applications constitute an implicit component of contemporary notions of intelligence (Maynard, Subrahmanyam, & Greenfield, 2005). The ecological techno-subsystem furthers our understanding of environmental influences on child development by emphasizing the impact of digital technologies on cognitive growth during childhood. The techno-subsystem provides precise description of microsystemic mechanisms of developmental influence which lead to intervention strategies. According to Livingston and Bober (2005), many parents lack the skills to guide and support their children's Internet use and Internet-literate parents have Internet-literate children. Subsequent research may evaluate the effectiveness of techno-subsystem interventions for elementary school children at-risk, for example, the provision of home Internet access and parent Internet literacy training. As stated elsewhere, "current anxiety surrounding children's Internet use should be for those whose cognitive processes are not influenced by the cultural tool" (Johnson, 2006, p. 570).

Limitations and Future Research

In the current investigation, children's use of the Internet at home was determined by parent-report (common in the literature, e.g., Livingston & Bober, 2005; Rideout, Vandewater, & Wartella, 2003). The validity of such approaches, however, has been questioned and alternatives suggested including asking the child directly (Media Awareness Network, 2006; Roberts, Foehr, & Rideout, 2005) and standardized measures such as the *Internet Vocabulary Test for Children* (Johnson, 2007b). In the current investigation, indices of children's use of the Internet at home were obtained with objective (i.e., years of home Internet access) and subjective (*what does your child do when he/she uses the Internet at home*) parental response to questionnaire items. Alternative indices of children's use of the Internet may not replicate current findings.

Type of child online behavior (learn, play, browse, and communicate) emerged from thematic analysis of parent response to an open-ended questionnaire item. Alternative abstraction is apparent. For example, parental response to the open-ended item, *what does your child do when he/she uses the Internet at home*, may be dichotomized into directed versus undirected or focused versus unfocused use of the Internet. Responses such as *schoolwork*, *math practice*, *research for assignments*, *email* and *chat* may be interpreted as reflecting goal-directed and focused behavior; responses such as *play games*, *have fun with friends*, *visit websites*, and *find things of interest* refer to behavior that is unfocused and undirected. As opposed to online learning and communication, it may be that focused and goal-directed Internet use contributes to cognitive development during childhood.

Childhood use of the Internet occurs in three contexts: home, school, and community. From an ecological perspective, Internet use in one environment influences Internet use in other environments. Because all children in the sample attended the same elementary school, school-based Internet experience was assumed equivalent. However, Gibson and Oberg (2004) noted that the quality of school-based Internet experience varies widely across classrooms. Subsequent theoretical and empirical research may expand techno-subsystem description to include child-peer interactions during home, school, and community Internet use.

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